Application of stratigraphic frameworks and thermochronological data on the Mesozoic SW Gondwana intraplate environment to retrieve the Paraná-Etendeka plume movement

Corresponding author: Florian C. Krob, Institute of Earth Sciences, Heidelberg University,
Im Neuenheimer Feld 234, 69120 Heidelberg, Germany,
Florian.Krob@geow.uni-heidelberg.de, Telephone: +49-6221-4836

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Application of stratigraphic frameworks and thermochronological data on the Mesozoic SW Gondwana intraplate environment to retrieve the Paraná-Etendeka plume movement

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Florian C. Krob [a,*], Ulrich A. Glasmacher [a], Hans-Peter Bunge [b], Anke M. Friedrich [c], Peter C. Hackspacher [d]

[a] Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany
[b] Department of Earth and Environmental Sciences, Geophysics, LMU, Theresienstraße 41, 80333 Munich, Germany
[c] Department of Earth and Environmental Sciences, Geology, LMU, Luisenstraße 37, 80333 Munich, Germany
[d] Departamento de Petrologia e Metalogenia, Instituto de Geociências e Ciências Exatas, Universidade Estadual Paulista, Av. 24-A, 1515, Bela Vista, 13506-900 Rio Claro, SP, Brazil

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A B S T R A C T

Since plate tectonics has been linked to material flow in the Earth's mantle, it is commonly accepted that convective motion in the sublithospheric mantle results in vertical deflections and horizontal plate motion on the Earths surface. Those mantle flow-driven vertical deflections are recognized through significant signals and traces in the sedimentary records (unconformities and missing sections). Recently, Friedrich et al. (2018) introduced an event-based plume stratigraphic framework that uses such signals in the stratigraphic record to detect the geological evolution near, and on the Earth's surface in areas of interregional scale caused by mantle plume movement. Information about these dynamic processes is stored in geological archives, such as (1) stratigraphic records of sedimentary basins and (2) thermochronological data sets of igneous, metamorphic, and sedimentary rocks.

For the first time, this research combines these two geological archives and applies them to the Mesozoic SW Gondwana intraplate environment to retrieve the Paraná-Etendeka plume movement prior to the Paraná-Etendeka LIP. We compiled 18 stratigraphic records of the major continental and marine sedimentary basins and over 35 thermochronological data sets including >1300 apatite fission-track ages surrounding the Paraná-Etendeka Large Igneous Province to test the event-based plume stratigraphic framework and its plume stratigraphic mapping to retrieve the timing and spatial distribution of the Paraná-Etendeka plume.

The plume stratigraphic mapping, using the stratigraphic records is suitable to demark a possible plume center, plume margins and distal regions (Friedrich et al., 2018). Thermochronological data reveal centers of a significant thermal Paraná-Etendeka plume influence. Both archives show significant signals and traces of mantle plume movement well in advance of the flood basalt eruptions. Our LTT data combined with stratigraphic records are modeled successfully with respect to a viable mantle plume driven thermal evolution and therefore, we suggest that thermochronological data, in combination with stratigraphy records have the potential to retrieve the Paraná-Etendeka plume movement.

1. Introduction

Ever since plate tectonics has been linked to material flow in the Earth's mantle (Wilson, 1963, 1965; Davies and Richards, 1992), it is commonly accepted that convective motion in the sublithospheric mantle results in vertical deflections and horizontal plate motion on the Earth's surface (Davies, 1999; Davies et al., 2019). Those mantle flow-driven vertical deflections, known as 'dynamic topography' (Hager et al., 1985; Braun, 2010), have attracted considerable attention lately (Bunge and Glasmacher, 2018). Evidence for dynamic topography changes over geologic time comes from passive continental margins, in particular in the South Atlantic region (Paton et al., 2008; Guillocheau et al., 2012; Autin et al., 2013; Dressel et al., 2015), where spreading rate changes appear to correlate with uplift events, presumably owing to variations of upper mantle flow (Colli et al., 2013; Colli et al., 2014; Brune et al., 2016). Dynamic topography thus links to the convective mantle flow regime. Theoretical considerations based on the dynamic topography response of Earth models to internal loads (e.g., hot rising plumes or cold sinking lithosphere) imply that the Earth's surface sustains deflections on the order of ±1 km (Colli et al., 2016), resulting in significant signals and traces in the sedimentary records (unconformities and missing sections, e.g., Stille, 1919).

* Corresponding author.
E-mail address: florian.krob@geow.uni-heidelberg.de (F.C. Krob).

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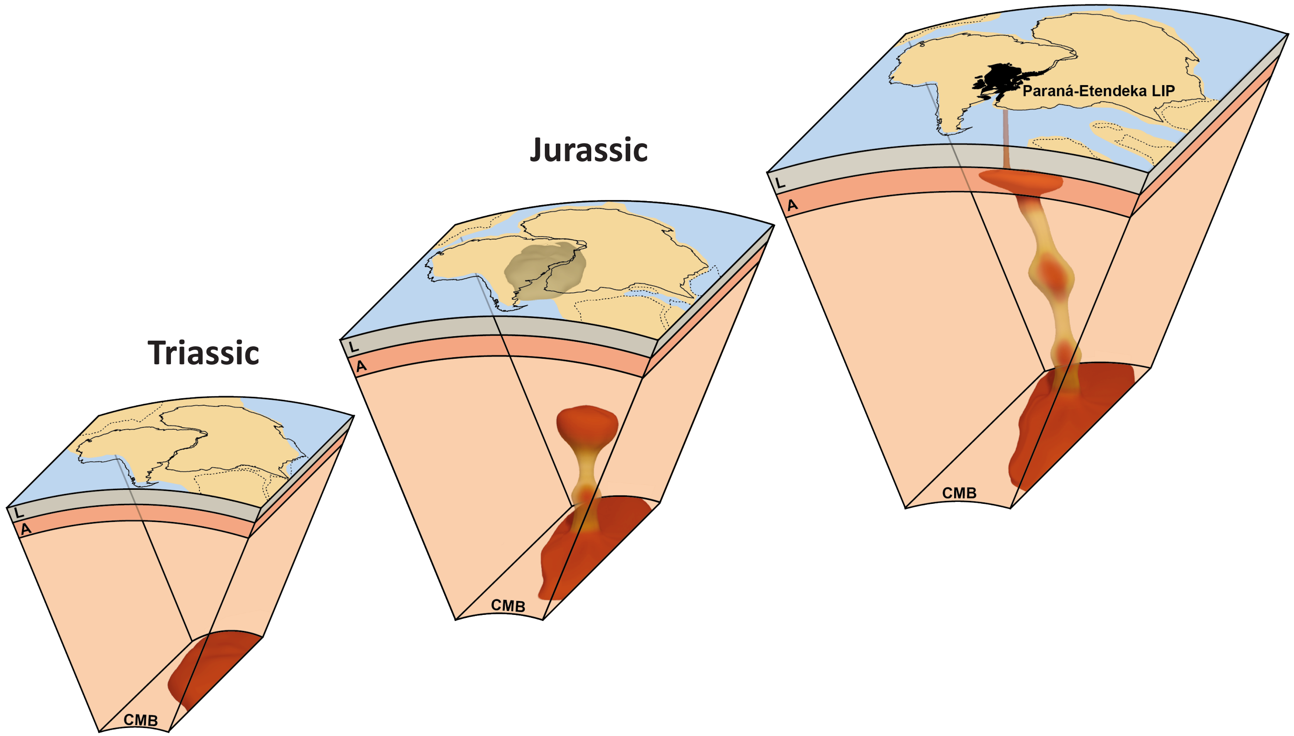

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ORIGINAL PAPER

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Late Neoproterozoic-to-recent long-term *t–T*-evolution of the Kaoko and Damara belts in NW Namibia

Florian C. Krob[1] · Daniel P. Eldracher[1] · Ulrich A. Glasmacher[1] · Sabine Husch[1] · Eric Salomon[2] · Peter C. Hackspacher[3] · Nortin P. Titus[4]

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Abstract

This research aims to reconstruct the Late Neoproterozoic-to-recent long-term time–temperature-evolution of the NW Namibian Kaoko and Damara belts combining numerical modeling of new thermochronological data with previously published geochronological data, i.e., U–Pb, Sm–Nd, and Rb–Sr analyses, and K/Ar, $^{40}Ar/^{39}Ar$ low-temperature thermochronology. Consequently, we retrieve a coherent long-term time–temperature-evolution of the NW Namibian Neoproterozoic basement rocks including rates of exhumation and subsidence periods over the last ~ 500 Myr. Neoproterozoic basement rocks indicate fast post-Pan African/Brasiliano cooling and exhumation, reheating, or rather subsidence during the development of the Paleozoic-to-Mesozoic SW Gondwana intraplate environment and a significant thermal overprint of the rocks during South Atlantic syn- to post-rift processes, and therefore, resemble the opponent SE Brazilian time–temperature-evolution. We provide an overview of thermochronological data including new apatite and zircon fission-track data derived from Neoproterozoic, Late Paleozoic, and Lower Cretaceous rocks. Apatite fission-track ages range from 390.9 ± 17.9 Ma to 80.8 ± 6.0 Ma in the NW Kaoko Belt with youngest ages confined to the coastal area and significant age increase towards the inland. New zircon apatite fission-track data reveal ages between 429.5 ± 47.8 and 313.9 ± 53.4 Ma for the rocks of the Kaoko Belt. In the central Damara Belt, new apatite fission-track ages range between 138.5 ± 25.3 Ma to 63.8 ± 4.8 Ma. Combined apatite fission-track age distributions from Angola to Namibia and SE Brazil correlate for both sides of the South Atlantic passive continental margin and the reset AFT ages overlap with the lateral Paraná–Etendeka dike swarm distribution.

Keywords Long-term *t–T*-evolution · Thermochronology · Numerical modeling · South Atlantic passive continental margin of NW Namibia

Florian C. Krob and Daniel P. Eldracher have contributed equally to this study.

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✉ Florian C. Krob
florian.krob@geow.uni-heidelberg.de

[1] Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234, 69120 Heidelberg, Germany

[2] Department of Earth Sciences, University of Bergen, Realfagbygget, Allégt. 41, 5020 Bergen, Norway

[3] Departamento de Petrologia e Metalogenia, Instituto de Geosciências e Ciências Exatas, Universidade Estadual Paulista, Av. 24-A, 1515, Bela Vista, Rio Claro, SP 13506-900, Brazil

[4] Ministry of Mines and Energy, Geological Survey of Namibia, Private Bag 13297, Winhoek, Namibia

Introduction

Precambrian metamorphic and magmatic rocks are important archives that have stored information about long-term landscape forming processes, e.g., extensive and localized tectonic and volcanic activity, surface uplift and erosion (exhumation), and crustal scale subsidence. These long-term landscape forming processes are related to upper mantle and crustal tectono-thermal dynamics, which can be reconstructed from the long-term time (t)–temperature (T)-evolution of rocks in specific geological environments, i.e., along passive continental margins around the world (e.g., Brown et al. 2014; Green et al. 2015, 2018; Japsen et al. 2012, 2014; Braun 2018).

Until recently, most of the research along the South Atlantic passive continental margin (SAPCM) in NW Namibia was either focused on the Precambrian deformation, the

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Multi-chronometer thermochronological modelling of the Late Neoproterozoic to recent t-T-evolution of the SE coastal region of Brazil

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Florian C. Krob[a,*], Ulrich A. Glasmacher[a], Markus Karl[a], Melissa Perner[a], Peter C. Hackspacher[b], Daniel F. Stockli[c]

[a] *Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234, 69120, Heidelberg, Germany*
[b] *Departamento de Petrologia e Metalogenia, Instituto de Geosciências e Ciências Exatas, Universidade Estadual Paulista, Av. 24-A, 1515, Bela Vista, 13506-900, Rio Claro, SP, Brazil*
[c] *Department of Geological Sciences, University of Texas, Austin, 1 University Station C9000, Austin, TX, 78712-0254, USA*

ABSTRACT

South-eastern Brazil is as an important geological archive for understanding and reconstructing various plate tectonic stages of the Wilson Cycle. In the Neoproterozoic, the area of the today's South Atlantic passive continental margin (SAPCM: e.g. between São Paulo and Laguna) of south-eastern Brazil underwent subduction, followed by the collision of the contemporary plates of South America and Africa creating a Neoproterozoic orogeny within the supercontinent Gondwana. During the Palaeozoic and Lower Mesozoic (stage 1), the future SAPCM, as an intracratonic area, experienced erosion, denudation of the Neoproterozoic mobile belts (Pan African/Brasiliano orogeny), and large basin formation (Paraná Basin) (stage 2). Possibly plume-driven pre-to syn-rift (embryonic), ocean spreading (juvenile), and post-break up (mature) processes led to the recent evolution of the SAPCM since the Upper Mesozoic (stage 3).

For the first time, this research aims to reconstruct the syn-to post-orogenic t-T-evolution of Neoproterozoic basement rocks of the SE coastal region of Brazil covering the entire geological evolution since the Late Neoproterozoic. Therefore, this study uses geochronological and thermochronological data combined with numerical modelling. This includes published geochronological data of Neoproterozoic basement samples such as U-Pb, Sm-Nd and Rb-Sr analyses, and low temperature thermochronology (LTT) data revealed by K/Ar, $^{40}Ar/^{39}Ar$ analyses. To this existing LTT data set, we report new apatite (AFT) and zircon (ZFT) fission-track, and (U-Th-Sm)/He (AHe, ZHe) data. Numerical modelling of that LTT data attached to the existing geochronological data indicates the following evolution:

- Stage 1: In the central part of the future SAPCM, the Pan African/Brasiliano post-orogenic cooling and exhumation (uplift and erosion of Neoproterozoic rocks to the surface) history occurs in three phases: (i) rapid Late Neoproterozoic exhumation, (ii) a period of relative thermal stability (temperatures of about 200–300 °C) in which rocks reside at upper crust levels during the Early Cambrian to Devonian, and (iii) a second rapid exhumation phase moving the Neoproterozoic basement rocks to the surface during the Devonian. The northern and southern parts indicate a distinct post-orogenic exhumation suggesting faster cooling and exhumation from the Late Neoproterozoic to Devonian/Carboniferous than in the central section.
- Stage 2: A phase of subsidence leading to the formation of the Paraná Basin followed by pre-to syn-rift processes and the emplacement of the Paraná-Etendeka flood basalts.
- Stage 3: Post-South Atlantic break up processes, such as erosion and exhumation.

1. Introduction

"Passive" continental margins are "first-order" archives of the Earth's surface documenting information from the interplay of endogene and exogene forces. The South Atlantic passive continental margin (SAPCM) in south-eastern Brazil not only provides information related to continental rifting, syn-to post-break up dynamics, and climate changes, but also stores the syn-to post-Late Neoproterozoic evolution since the assembly of West Gondwana. The large scale Pan African/Brasiliano orogeny (Pimentel et al., 1999) included the amalgamation of several cratons and microplates around the São Francisco-Congo (SFC) Craton. During the Early Palaeozoic post-orogenic regional uplift and erosion triggered cooling and denudation of the Neoproterozoic mobile belts (Soares et al., 2001, 2008; Santos et al., 2015; Valeriano et al., 2008; Florisbal et al., 2012). Deposition of the material eroded at that time caused subsidence of the Paraná Basin (Basei et al., 2010). Since the Upper Mesozoic, the SAPCM in south-eastern Brazil was subject of pre-to syn-rift, ocean spreading, and post-break up processes.

Neoproterozoic metamorphic and magmatic rocks characterize the exposed geology between São Paulo and Florianópolis (Fig. 1). The Neoproterozoic basement is cut by mafic dykes of Lower Cretaceous, and alkaline to carbonatite intrusions of Early and Late Cretaceous age. To the West, the basement is overlain by Palaeozoic and Mesozoic

* Corresponding author.
E-mail address: florian.krob@geow.uni-heidelberg.de (F.C. Krob).

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